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FRACTAL DIMENSION AND HYPSONETRY:  
IMPLICATIONS FOR LANDSCAPE  
EVOLUTION IN THE CENTRAL TRANSVERSE  
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## ANNUAL STATUS REPORT

### **LITHOLOGIC AND STRUCTURAL INFLUENCES ON LANDSCAPE FRACTAL DIMENSION AND HYPSONETRY: IMPLICATIONS FOR LANDSCAPE EVOLUTION IN THE CENTRAL TRANSVERSE RANGES, CALIFORNIA**

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#### SUMMARY OF ACTIVITIES

Our principal goal for this project is to evaluate how spatial variation in long-term erosion rates contributes to the formation of an approximately fractal landscape. Towards this end, we developed tools during the first year of this project with which to derive such erosion rate information from in situ-produced cosmogenic  $^{14}\text{C}$  within sediments of the Walnut Gulch Experimental Watershed, Arizona (Walnut Gulch). In addition, the second project year yielded powerful software tools for analyzing topographic variability of DEMs over a variety of scale lengths, drainage basin magnitudes, and grid resolutions. However, these techniques cannot help us attain our project objectives without the ability to consistently extract the cosmogenic  $^{14}\text{C}$  from bedrock and soils, while eliminating contaminant  $^{14}\text{C}$ . We have thus concentrated our efforts this year on developing reliable equipment and methods for isolating and extracting the cosmogenic  $^{14}\text{C}$  signal from rock materials. Particularly exciting results include the stabilization of critical portions of our total background  $^{14}\text{C}$  at levels less than 50% of our previous values, with a concomitant reduction in scatter about the mean of approximately 70%.

#### EXTRACTION LINE REDESIGN AND TESTING

As previously reported (Annual Status Report dated 27 May, 1994), we have been unable to reproduce our preliminary cosmogenic  $^{14}\text{C}$  production rate estimates. Reliable production rate estimates form the basis for any application of in situ-produced cosmogenic nuclides to geomorphic problems. Thus, our top priority for this project is now to demonstrate that we can reliably and reproducibly extract in situ  $^{14}\text{C}$  from rock materials, while simultaneously reducing contaminant  $^{14}\text{C}$  to negligible levels.

We have thus endeavored to identify and reduce or eliminate sources of variability in our extraction procedures. As previously reported (Annual Status Report dated 27 May, 1994), careful analysis of our results suggested that we were unable (1) to adequately control the temperature and/or oxidizing conditions in the sample crucible using an induction furnace, and (2) to adequately remove other gases released with the  $\text{CO}_2$  during the melting of the rock. We thus modified our extraction procedures and purchased a new  $1700^\circ\text{C}$  resistance furnace to melt our samples.

The new furnace was delivered at the end of May 1994, but unfortunately was not hooked up until mid-September for several reasons. First, we had to wait for several additional parts for the system before we could begin using it. Second, we had to modify the extraction line to accommodate the new furnace. Finally, and as it turned out, most significantly, since Dr. Timothy Jull of the NSF-Arizona Accelerator Mass Spectrometry Facility paid for the furnace, he specified that the AMS facility's electrical engineer hook up the high voltage power to the furnace (to save some money) because he does excellent work. Dr. Jull then left town for a series of conferences for five weeks. However, the electrical engineer's first priority is maintaining the accelerator mass spectrometer in peak condition, and it was experiencing a number of problems during late July and August that required his full attention. We did not have the authority to tell the electrician to delay his accelerator modifications for the one to two days required for the furnace hookup, but kept after him daily to see if he could work our job into his busy schedule. On his return in mid-August, Dr. Jull recognized that the situation needed his intervention. He had the engineer contact the University's

electricians to install the additional circuits needed for the furnace, but there was another delay until the electricians could fit the job into their schedule. Eventually, the engineer completed the final wiring himself in mid-September.

Once operational, we began to investigate the behavior of the alumina furnace tube under a variety of conditions, since this was one of the biggest unknowns in our system. We baked the tube on and off for several days at approximately 1600°C to drive off any absorbed contaminants, and proceeded to assess our yields of CO<sub>2</sub> with the line isolated from the vacuum system for simulated three-hour sample runs. This is three times longer than any previous runs we had done in our previous experiments with other furnaces, so we were concerned about the potential for high background levels of carbon. One room-temperature run and two runs at 1500 and 1600°C were extremely promising. All yielded CO<sub>2</sub> volumes which were an order of magnitude lower than our induction furnace blanks.

However, our results degenerated immediately after these runs. A week-and-a-half of experiments at various temperatures between 1450 and 1600°C yielded CO<sub>2</sub> volumes two orders of magnitude higher than the first three runs. A search for the source of this increased yield resulted in our discovery that our entire extraction line was full of hydrocarbon vapors, apparently derived from our roughing (low) vacuum pump. This diffusion of pump oil vapors (called backstreaming) is well-known in oil-based high-vacuum pumping systems, and most are designed to minimize this problem. These vapors had overwhelmed a trap on the roughing pump designed to catch them. Unfortunately, when we initially installed this trap we were not told that the molecular sieve material within the trap needed to be baked out once or twice per week to remain effective. In addition, the high-vacuum diffusion pump on our system backstreamed as well (albeit at lower rates), and its silicone oil was contaminated by the roughing pump oil. Our procedures and system were designed to minimize backstreaming from the diffusion pump when it was running, but might not have prevented it as the pump cooled down at the end of the day, with the liquid nitrogen trap off. Thus, both pumps may have contributed to our problem.

We have now thoroughly cleaned all portions of our extraction system. The glass and alumina portions were cleaned with several acetone and/or isopropanol rinses, followed by thorough rinsing in deionized water. Those portions were then fired in air in the campus glass blowers' kiln at approximately 580°C. However, it turned out to be more difficult and time-consuming than previously imagined to clean the metallic portions of the line. Because they could not be fired at high temperatures in air without significant oxidation, we needed to rely primarily on solvents and detergents to clean these pieces. However, we discovered that many of these cleaning agents left hydrocarbon residues on the metal surfaces when used alone. Through much trial and error, we found a series of detergent, acid and solvent washes (used in concert with vacuum heating to between 75°C and 250°C) which removed all significant traces of carbon compounds from the metal parts.

We also redesigned critical portions of our extraction line to prevent future contamination problems. We purchased a better trapping system for our roughing pump, and an entirely new diffusion pump designed to reduce backstreaming to negligible levels – all using funds provided by Dr. Jull. These changes, along with complementary changes in operating procedures, should effectively eliminate backstreaming problems from future line operation.

In addition, we built a graphitization line dedicated to in situ <sup>14</sup>C samples, with similar protection against backstreaming, again with funds provided by Dr. Jull. The graphitization lines currently used by the AMS facility do not have such protection, although their design is adequate for samples with high <sup>14</sup>C levels (such as traditional radiocarbon samples). This new line should thus give us complete control over all aspects of our sample preparation process, and position us for the best possible chances of success in making this technique work.

Our new extraction and graphitization lines are now fully operational. We have been running extensive tests over the last three months to (1) determine baseline background  $^{14}\text{C}$  levels to be expected during line operation, and (2) assess how variation in potential operating procedures may affect those background levels. We have collected over 40 samples to date, including 24 procedural samples. In addition to  $^{14}\text{C}$  data, we will also collect  $^{13}\text{C}$  and  $^{18}\text{O}$  isotopic information for our samples. A thorough understanding of the behavior of these isotopic systems in the extraction and graphitization lines should enable us to spot potential deviations from "normal line operation," and thus help ensure collection of the highest quality data.

We analyzed our graphitization blanks first, because if there were problems in that line, we needed to take steps to mediate them before analyzing our extraction line samples. AMS results from twelve such blanks are quite promising, with a mean  $^{14}\text{C}$  value less than half of our previous value using our older extraction line and the standard graphitization lines used by the AMS lab. Our graphitization blank is now as good or slightly better than those of the standard graphitization lines. In addition, we have sharply reduced the scatter in our graphitization blanks by about 60 to 70% over what we had experienced previously using the graphitization lines in the AMS lab. Measurements of  $^{13}\text{C}$  and  $^{18}\text{O}$  isotopic ratios in the same samples are similarly stable. We are now proceeding with analysis of our extraction line samples.

Thus, while we have encountered significant impediments to our progress during the past two years, we have also made impressive strides in extraction and graphitization line design and operation. These improvements give us the best chance of success with our in situ  $^{14}\text{C}$  extraction techniques – methods critical to our planned process-oriented studies of landscape evolution.